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GISTS FROM AGASSIZ

OR

PASSAGES ON THE INTELLIGENCE WORKING IN NATURE

La gloria di colui che tutto move
per l' universo penetra e risplende
in una parte più e meno altrove.
Par. i. 1-3.

selected by

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LOUIS AGASSIZ

Born in 1807 at Motier, Switzerland.

Student of Cuvier and Humboldt.

1832–1845: Professor of Natural History at University of Neuchatel.

Publication of "Poissons Fossiles" (1833-1843).
Investigated Alpine glaciers.
Founded and personally directed lithographic press "to raise the standard of execution in works of a purely scientific character."

1846: Lectured at Lowell Institute in Boston.

1848: Appointed to Chair of Natural History at Harvard.

Journey to Lake Superior.
Exploration of Florida Reefs.
Publication of "Contributions to Natural History of the United States" (1855) and "Essay On Classification" (1859).

1859: Founded Museum of Comparative Anatomy at Cambridge.

1865-66: Journey to Brazil.

1872: Founded first scientific summer school at Penikese Island.

Died at Cambridge, Massachusetts, 1873.

Important works include: Essay On Classification, Methods of Study in Natural History, Geological Sketches, The Structure of Animal Life, Journey to Brazil, and Life and Correspondence (edited by E. C. Agassiz.)

There is a singular lack of logic, as it seems to me, in the views of the materialistic naturalists. While they consider classification, or, in other words, their expression of the relations between animals or between physical facts of any kind, as the work of their intelligence, they believe the relations themselves to be the work of physical causes. The more direct inference surely is, that, if it requires an intelligent mind to recognize them, it must have required an intelligent mind to establish them. These relations existed before man was created; they have existed ever since the beginning of time; hence, what we call the classification of facts is not the work of his mind in any direct original sense, but the recognition of an intelligent action prior to his own existence.

No thoughtful naturalist can silence the suggestions, continually arising in the

course of his investigations, respecting the origin and deeper connection of all living beings; but he is the truest student of nature who, while seeking the solution of these great problems, admits that the only true scientific system must be one in which the thought, the intellectual structure, rises out of and is based upon facts.

"A physical fact is as sacred as a moral principle. Our own nature demands from us this double allegiance."

COMPARISON

It is deeply to be lamented that so many naturalists have entirely overlooked this significant advice of Cuvier's, with respect to combining zoölogical and anatomical studies in order to arrive at a clearer perception of the true affinities among animals. To sum it up in one word, he tells us that the secret of his method is "comparison," — ever comparing and comparing throughout the enormous range of his knowledge of the organization of animals, and founding upon the differences as well as the similarities those broad generalizations under which he has included all animal structures.

And this method, so prolific in his hands, has also a lesson for us all. In this country there is a growing interest in the study of Nature; but while there exist hundreds of elementary works illustrating the native animals of Europe, there are few such books here to satisfy the demand for information respecting the animals of our land and water. We are thus forced to turn more and more to our own investigations and less to authority; and the true method of obtaining independent knowledge is this very method of Cuvier's, — comparison.

Let us make the most common application of it to natural objects. Suppose we see together a Dog, a Cat, a Bear, a Horse, a Cow, and a Deer. The first feature that strikes us as common to any two of them is the horn in the Cow and Deer. But how shall we associate either of the others with these? We examine the teeth, and find those of the Dog, the Cat, and the Bear sharp and cutting, while those of the Cow, the Deer, and the Horse have flat surfaces, adapted to grinding and chewing, rather than cutting and tearing. We compare these features of their structure with the habits of these animals, and find that the first are carnivorous, that they seize and tear their prey, while the others are herbivorous or grazing animals, living only on vegetable substances, which they chew and grind. We compare further the Horse and Cow, and find that the Horse has front teeth

both in the upper and lower jaw, while the Cow has them only in the lower; and going still further, and comparing the internal with the external features, we find this arrangement of the teeth in direct relation to the different structure of the stomach in the two animals, — the Cow having a stomach with four pouches, adapted to a mode of digestion by which the food is prepared for the second mastication, while the Horse has a simple stomach. Comparing the Cow and the Deer, we find that the digestive apparatus is the same in both; but though they both have horns, in the Cow the horn is hollow, and remains through life firmly attached to the bone, while in the Deer it is solid and is shed every year. With these facts before us, we cannot hesitate to place the Dog, the Cat, and the Bear in one division, as carnivorous animals, and the other three in another division as herbivorous animals, — and looking a little further, we perceive, that, in common with the Cow and the Deer, the Goat and the Sheep have cloven feet, and that they are all ruminants, while the Horse has a single hoof, does not ruminate, and must therefore be separated from them, even though, like them, he is herbivorous.

This is but the simplest illustration, taken from the most familiar objects, of this comparative method; but the same process is equally applicable to the most intricate problems in animal structures, and will give us the clew to all

true affinities between animals. The education of a naturalist now consists chiefly in learning how to compare. If he have any power of generalization, when he has collected his facts, this habit of mental comparison will lead him up to principles, and to the great laws of combination. It must not discourage us, that the process is a slow and laborious one, and the results of one lifetime after all very small. It might seem invidious, were I to show here how small is the sum total of the work accomplished even by the great exceptional men, whose names are known throughout the civilized world. But I may at least be permitted to speak disparagingly of my own efforts, and to sum up in the fewest words the result of my life's work. I have devoted my whole life to the study of Nature, and yet a single sentence may express all that I have done. I have shown that there is a correspondence between the succession of Fishes in geological times and the different stages of their growth in the egg, — this is all. It chanced to be a result that was found to apply to other groups and has led to other conclusions of a like nature. But, such as it is, it has been reached by this system of comparison, which, though I speak of it now in its application to the study of Natural History, is equally important in every other branch of knowledge. By the same process the most mature results of scientific research in Philology, in Ethnology, and in Physical Science are reached.

HOMOLOGY and ANALOGY

We must carefully distinguish between affinity and analogy among animals. The former is founded on identity of plan; the latter only upon external resemblance. This may be produced by similar features, which, when intimately connected with the whole internal organization, as in some groups, may be considered as typical characters, but when only grafted, as it were, in a superficial manner on animals of another type, have no relation to the essential elements of structure, and become at once subordinate and unimportant. Such is the difference between the tentacles in a Radiate and the wreath of feelers in a Worm; — the external effect may be much the same; but in the former every tentacle opens into one of the chambers, as in a Polyp, or connects with one of the radiating tubes, as in Acalephs, or with the locomotive suckers, as in Star-Fishes, and is therefore closely linked with the whole internal organization; whereas the feelers in the latter are only external appendages, in no way connected with the essential structural elements. We have a striking illustration of this superficial resemblance in the wings of Birds and Insects. In Birds, wings are a typical feature, corresponding to the front limbs in all Vertebrates, which are constructed in the same way, whether they are arms as in Man, or fore-legs as in Quadrupeds, or pectoral fins as in Fishes, or wings as in Birds. The wing in an Insect, on the contrary, is a

flattened, dried-up gill, having no structural relation whatever to the wing of a Bird. They are analogous only, because they resemble each other in form and in function, being in the same way subservient to flight; but as organs they are entirely different. The wings of Birds are homologous to the limbs of other Vertebrates, notwithstanding their great apparent difference; they are only analogous to the wings of Insects, notwithstanding their great external resemblance.

CLASSIFICATION

CONSIDERATIONS

Classification seems to me to rest upon too narrow a foundation when it is chiefly based upon structure. Animals are linked together as closely by their mode of development, by their relative standing in their respective classes, by the order in which they have made their appearance upon earth, by their geographical distribution, and generally by their connection with the world in which they live, as by their anatomy. All these relations should, therefore, be fully expressed in a natural classification; and, though structure furnishes the most direct indication of some of these relations, always appreciable under every circumstance, other considerations should not be neglected, which may complete our insight into the general plan of creation.

In characterizing the great branches of the animal kingdom, it is not enough to indicate the plan of their structure in all its peculiarities; there are possibilities of execution which are at once suggested, to the exclusion of others, and which should also be considered, and so fully analyzed, that the various modes in which such a plan may be carried out shall at once be made apparent. The range and character of the general homologies of each type should also be illustrated, as well as the general conditions of existence of its representatives. In characterizing classes, it ought to be shown why such groups constitute a class, and not merely an order or a family; and, to do this satisfactorily, it is indispensable to trace the special homologies of all the systems of organs which are developed in them. It is not less important to ascertain the foundation of all the subordinate divisions of each class; to know how they differ, what constitutes orders, what families, what genera, and upon what characteristics species are based in every natural division.

NATURAL DIVISIONS AMONG ANIMALS

Branches or *types* are characterized by the plan of their structure;

Classes, by the manner in which that plan is executed, as far as ways and means are concerned;

Orders, by the degrees of complication of that structure;

Families, by their form, as far as determined by structure;

Genera, by the details of the execution in special parts; and

Species, by the relations of individuals to one another and to the world in which they live, as well as by the proportions of their parts, their ornamentation, etc.

TYPES

We must come down to the last century, to Linnæus, before we find the history taken up where Aristotle had left it, and some of his suggestions carried out with new freshness and vigor. Aristotle had already distinguished between genera and species; Linnæus took hold of this idea, and gave special names to other groups, of different weight and value. Besides species and genera, he gives us orders and classes, — considering classes the most comprehensive, then orders, then genera, then species. He did not, however, represent these groups as distinguished by their nature, but only by their range; they were still to him, as genera and species had been to Aristotle, only larger or smaller groups, not founded upon and limited by different categories of structure. He divided the animal kingdom into six classes, which I give here, as we shall have occasion to compare them with other classifications: — *Mammalia*, *Birds*, *Reptiles*, *Fishes*, *Insects*, and *Worms*.

That this classification should have expressed all that was known, in the last century, of the most general relations among animals, only shows how difficult it is to generalize on such a subject; nor should we expect to find it an easy task,

when we remember the vast number of species (about a quarter of a million) already noticed by naturalists. Linnæus succeeded, however, in finding a common character on which to unite most of his classes; but his definition of the class of Mammalia, that group to which we ourselves belong, remained very imperfect. Indeed, in the earlier editions of his classification, he does not apply the name of Mammalia to this class, but calls the higher animals *Quadrupedia*, characterizing them as the animals with four legs and covered with fur or hair, that bring forth living young and nurse them with milk. In thus admitting external features as class characters, he excluded many animals which by their mode of reproduction, as well as by their respiration and circulation, belong to this class as much as the Quadrupeds, — as, for instance, all the Cetaceans (Whales, Porpoises, and the like), which, though they have not legs, nor are their bodies covered with hair or fur, yet bring forth living young, nurse them with milk, are warm-blooded and air-breathing. As more was learned of these animals, there arose serious discussion and criticism among contemporary naturalists respecting the classification of Linnæus, all of which led to a clearer insight into the true relations among animals. Linnæus himself, in his last edition of the "Systema Naturæ," shows us what important progress he had made since he first announced his views; for he there substitutes for the name of *Quadrupedia* that of *Mam-*

malia, including among them the Whales, which he characterizes as air-breathing, warm-blooded, and bringing forth living young which they nurse with milk. Thus the very deficiencies of his classification stimulated naturalists to new criticism and investigation into the true limits of classes, and led to the recognition of one most important principle, — that such groups are founded, not on external appearance, but on internal structure, and that internal structure, therefore, is the thing to be studied. The group of Quadrupeds was not the only defective one in this classification of Linnæus; his class of Worms, also, was most heterogeneous, for he included among them Shell-Fishes, Slugs, Star-Fishes, Sea-Urchins, Corals, and other animals that bear no relation whatever to the class of Worms as now defined.

But whatever its defects, the classification of Linnæus was the first attempt at grouping animals together according to certain common structural characters. His followers and pupils engaged at once in a scrutiny of the differences and similarities among animals, which soon led to a great increase in the number of classes; instead of six, there were presently nine, twelve, and more. But till Cuvier's time there was no great principle of classification. Facts were accumulated and more or less systematized, but they were not yet arranged according to law; the principle was still wanting by which to generalize them and give meaning and vitality to the

whole. It was Cuvier who found the key. He himself tells us how he first began, in his investigations upon the internal organization of animals, to use his dissections with reference to finding the true relations between animals, and how ever after his knowledge of anatomy assisted him in his classifications, while his classifications threw new light again on his anatomical investigations, — each science thus helping to fertilize the other. He was not one of those superficial observers who are in haste to announce every new fact that they chance to find, and his first paper* specially devoted to classification gave to the world the ripe fruit of years of study. This was followed by his great work, "Le Règne Animal." He said that animals were united in their most comprehensive groups, not on special characters, but on different *plans of structure*, — moulds, he called them, in which all animals had been cast. He tells us this in such admirable language, that I must, to do justice to his thought, give it in his own words:—

"Si l'on considère le règne animal d'après les principes que nous venons de poser en se débarrassant des préjugés établis sur les divisions anciennement admises, en n'ayant égard qu'à l'organisation et à la nature des animaux, et non pas à leur grandeur, à leur utilité, au plus ou moins de connaissance que nous en avons, ni à

* "Sur un nouveau rapprochement à établir entre les Classes qui composent le Règne Animal." — *Ann. Mus.*, Vol. XIX.

toutes les autres circonstances accessoires, on trouvera qu'il existe quatre formes principales, quatre plans généraux, si l'on peut s'exprimer ainsi, d'après lesquels tous les animaux semblent avoir été modelés, et dont les divisions ultérieures, de quelque titre que les naturalistes les aient décorées, ne sont que des modifications assez légères, fondées sur le développement ou l'addition de quelques parties, qui ne changent rien à l'essence du plan."*

The value of this principle was soon tested by its application to facts already known, and it was found that animals whose affinities had been questionable before were now at once referred to their true relations with other animals by ascertaining whether they were built on one or another of these plans. Of such plans or structural conceptions Cuvier found in the whole animal kingdom only four, which he called *Vertebrates*, *Mollusks*, *Articulates*, and *Radiates*.

With this new principle as the basis of investi-

* If we consider the animal kingdom according to the principles advanced above, — freeing ourselves at the same time from prejudices founded on previously established divisions, and looking at animals only with reference to their nature and organization, excluding their size, their utility, our greater or less familiarity with them, and all other accessory circumstances, — we shall find that there exist four principal forms, four general plans, if we may so express it, in accordance with which all animals seem to have been modelled, and the ulterior divisions of which, by whatever title naturalists may have dignified them, are only comparatively light modifications, founded on the development or the addition of some parts not affecting the essential elements of the plan.

gation, it was no longer enough for the naturalist to know a certain amount of features characteristic of a certain number of animals, — he must penetrate deep enough into their organization to find the secret of their internal structure. Till he can do this, he is like the traveller in a strange city, who looks on the exterior of edifices entirely new to him, but knows nothing of the plan of their internal architecture. To be able to read in the finished structure the plan on which the whole is built is now essential to every naturalist.

Each of these plans may be stated in the most general terms. In the *Vertebrates* there is a vertebral column terminating in a prominent head ; this column has an arch above and an arch below, forming a double internal cavity. The parts are symmetrically arranged on either side of the longitudinal axis of the body. In the *Mollusks*, also, the parts are arranged according to a bilateral symmetry on either side of the body, but the body has but one cavity, and is a soft, concentrated mass, without a distinct individualization of parts. In the *Articulates* there is but one cavity, and the parts are here again arranged on either side of the longitudinal axis, but in these animals the whole body is divided from end to end into transverse rings or joints movable upon each other. In the *Radiates* we lose sight of the bilateral symmetry so prevalent in the other three, except as a very subordinate element of structure ; the plan of this lowest type is an

organic sphere, in which all parts bear definite relations to a vertical axis.

We can therefore say, assuming that mere comparisons like those I have presented to you can be made, that, however diversified the animal kingdom may be, the beings are all constructed upon four plans only. There are none on the earth that we cannot easily refer to one of those four plans.

DISTINCTNESS OF TYPES

I should be glad to contribute my share towards removing the idea that science is the mere amassing of facts. It is true that scientific results grow out of facts, but not till they have been fertilized by thought. The facts must be collected, but their mere accumulation will never advance the sum of human knowledge by one step; it is the comparison of facts and their transformation into ideas that lead to a deeper insight into the significance of Nature. Stringing words together in incoherent succession does not make an intelligible sentence; facts are the words of God, and we may heap them together endlessly, but they will

teach us little or nothing till we place them in their true relations, and recognize the thought that binds them together as a consistent whole.

I have spoken of the plans that lie at the foundation of all the variety of the Animal Kingdom as so many structural ideas which must have had an intellectual existence in the Creative Conception independently of any special material expression of them. Difficult though it be to present these plans as pure abstract formulæ, distinct from the animals that represent them, I would nevertheless attempt to do it, in order to show how the countless forms of animal life have been generalized into the few grand, but simple intellectual conceptions on which all the past populations of the earth as well as the present creation are founded. In such attempts to divest the thought of its material expression, especially when that expression is multiplied in such thousand-fold variety of form and color, our familiarity with living animals is almost an obstacle to our success. For I shall hardly be able to allude to the formula of the Radiates, for instance, — the abstract idea that includes all the structural possibilities of that division of the Animal Kingdom, — without recalling to my readers a Polyp or a Jelly-Fish, a Sea-Urchin or a Star-Fish. Neither can I present the structural elements of the Mollusk plan, without reminding them of an Oyster or a Clam, a Snail or a Cuttle-Fish, — or of the Articulate plan, without calling

up at once the form of a Worm, a Lobster, or an Insect, — or of the Vertebrate plan, without giving it the special character of Fish, Reptile, Bird, or Mammal. Yet I insist that all living beings are but the different modes of expressing these formulæ, and that all animals have, within the limits of their own branch of the Animal Kingdom, the same structural elements, though each branch is entirely distinct.

One important truth already assumes great significance in the history of the growth of animals; namely, that whatever the changes may be through which an animal passes, and however different the aspect of these phases at successive periods may appear, they are always limited by the character of the type to which the animal belongs, and never pass that boundary. Thus, the Radiate begins life with characters peculiar to Radiates, and ends it without assuming any feature of a higher type. The Mollusk starts with a character essentially its own, in no way related to the Radiates, and never shows the least tendency to deviate from it, either in the direction of the Articulate or the Vertebrate types. This is equally true of the Articulates. At no stage of

growth are their young homologous to those of Mollusks or Radiates any more than to those of Vertebrates, and in their final development they stand equally isolated from all others. That this is emphatically true of the Vertebrates has already been fully recognized; and the facts known with reference to this highest type of the Animal Kingdom might have served as a warning against the loose statements still current concerning the so-called infusorial condition of the young Invertebrates. These results are of the highest importance at this moment, when men of authority in science are attempting to renew the theory of a general transmutation of all animals of the higher types out of the lower ones. If such views are ever to deserve serious consideration, and be acknowledged as involving a scientific principle, it will only be when their supporters shall have shown that the fundamental plans of structure characteristic of the primary groups of the Animal Kingdom are transmutable, or pass into one another, and that their different modes of development may lead from one to the other. Thus far Embryology has not recorded one fact on which to base such doctrines.

CLASSES

I have said that the Radiates are the lowest type among animals, embodying, under an infinite

variety of forms, that plan in which all parts bear definite relations to a vertical central axis. The three classes of Radiates are distinguished from each other by three distinct ways of executing that plan. I dwell upon this point; for we shall never arrive at a clear understanding of the different significance and value of the various divisions of the Animal Kingdom, till we appreciate the distinction between the structural conception and the material means by which it is expressed. A comparison will, perhaps, better explain my meaning. There are certain architectonic types, including edifices of different materials, with an infinite variety of architectural details and external ornaments; but the flat roof and the colonnade are typical of all Grecian temples, whether built of marble or granite or wood, whether Doric or Ionic or Corinthian, whether simple and massive or light and ornamented; and, in like manner, the steep roof and pointed arch are the typical characters of all Gothic cathedrals, whatever be the material or the details. The architectural conception remains the same in all its essential elements, however the more superficial features vary. Such relations as these edifices bear to the architectural idea that includes them all, do classes bear to the primary divisions or branches of the Animal Kingdom.

All know the story of the Butterfly with its three lives, as Caterpillar, Chrysalis, and Winged Insect. I speak of its three lives, but we must not forget that they make after all but one life, and that the Caterpillar is as truly the same being with the future Butterfly, as the child is the same being with the future man. The old significance of the word *metamorphosis* — the fabled transformation of one individual into another, in which so much of the imagination and poetical culture of the ancients found expression — still clings to us; and where the different phases of the same life assume such different external forms, we are apt to overlook the fact that it is one single continuous life. To a naturalist, metamorphosis is simply growth; and in that sense the different stages of development in animals that undergo their successive changes within the egg are as much metamorphoses as the successive phases of life in those animals that complete their development after they are hatched.

But to return to our Butterfly. In its most imperfect, earliest condition, it is Worm-like, the body consisting of thirteen uniform rings; but when it has completed this stage of existence, it passes into the Chrysalis state, during which the body has two regions, the front rings being soldered together to form the head and chest, while the hind joints remain distinct; and it is only when it bursts from its Chrysalis envelope, as a

complete Winged Insect, that it has three distinct regions of the body. Do not the different periods of growth in this highest order explain the relation of all the orders to each other? The earliest condition of an animal cannot be its highest condition, — it does not pass from a more perfect to a less perfect state of existence. The history of its growth is, on the contrary, the history of its progress in development; and therefore, when we find that the first stage of growth in the Winged Insect transiently represents a structural character that is permanent in the lowest order of its class, that its second stage of growth transiently represents a structural character that is permanent in the second order of its class, and that only in the last stage of its existence does the Winged Insect attain its complete and perfect condition, we may fairly infer that this division of the class of Insects into a gradation of orders, placing Centipedes lowest, Spiders next, and Winged Insects highest, is true to Nature.

This is not the only instance in which the embryological evidence confirms perfectly the anatomical evidence on which orders have been distinguished, and I believe that Embryology will give us the true standard by which to test the accuracy of our ordinal groups. In the class of Crustacea, for instance, the Crabs have been placed above the Lobsters by some naturalists, in consequence of certain anatomical features; but there may easily be a difference of individual

opinion as to the relative value of these features. When we find, however, that the Crab, while undergoing its changes in the egg, passes through a stage in which it resembles the Lobster much more than it does its own adult condition, we cannot doubt that its earlier state is its lower one, and that the organization of the Lobster is not as high in the class of Crustacea as that of the Crab. While using illustrations of this kind, however, I must guard against misinterpretation. These embryological changes are never the passing of one kind of animal into another kind of animal; the Crab is none the less a Crab during that period of its development in which it resembles a Lobster; it simply passes, in the natural course of its growth, through a phase of existence which is permanent in the Lobster, but transient in the Crab.

FAMILIES

The Turtles and Terrapins form another good illustration of family characters. They constitute together a natural Order, but are distinguished from each other as two Families very distinct in general form and outline. Among Fishes I may mention the Family of Pickerels, with their flat, long snout, and slender, almost

cylindrical body, as contrasted with the plump, compressed body and tapering tail of the Trout Family. Or compare, among Insects, the Hawk-Moths with the Diurnal Butterfly, or with the so-called Miller, — or, among Crustacea, the common Crab with the Sea-Spider, or the Lobsters with the Shrimps, — or, among Worms, the Leeches with the Earth-Worms, — or, among Mollusks, the Squids with the Cuttle-Fishes, or the Snails with the Slugs, or the Periwinkles with the Limpets and Conchs, or the Clam with the so-called Venus, or the Oyster with the Mother-of-Pearl shell, — everywhere, throughout the Animal Kingdom, difference of form points at difference of Families.

GENERA

Considering all these divisions of the Animal Kingdom from this point of view, it is evident that the more comprehensive ones must be those which are based on the broadest characters, — the Branches, as united upon plan of structure, standing of course at the head; next to these the Classes, since the general mode of executing the plan presents a wider category of characters than the complication of structure on which Orders rest; after Orders come Families, or the patterns of form in which these greater or less complications of structure are clothed; and, proceeding in the same way from more general to

more special considerations, we can have no other category of structure as characteristic of Genera than the details of structure by which members of the same Family may differ from each other, and this I consider as the only true basis on which to limit Genera, while it is at the same time in perfect accordance with the practice of the most eminent modern zoölogists.

Genera, then, are divisions of a more restricted character than any of those we have examined thus far. Some of them include only one Species, while others comprise hundreds; since certain definite combinations of characters may be limited to a single Species, while other combinations may be repeated in many. We have striking examples of this among Birds: the Ostrich stands alone in its Genus, while the number of Species among the Warblers is very great. Among Mammalia the Giraffe also stands alone, while Mice and Squirrels include many Species. Genera are founded, not, as we have seen, on general structural characters, but on the finish of special parts, as, for instance, on the dentition. The Cats have only four grinders in the upper jaw and three in the lower, while the Hyenas have one more above and below, and the Dogs and Wolves have two more above and two more

below. In the last, some of the teeth have also flat surfaces for crushing the food, adapted especially to their habits, since they live on vegetable as well as animal substances. The formation of the claws is another generic feature. There is a curious example with reference to this in the Cheetah, which is again a Genus containing only one Species. It belongs to the Cat Family, but differs from ordinary Lions and Tigers in having its claws so constructed that it cannot draw them back over the paws, though in every other respect they are like the claws of all the Cats. But while it has the Cat-like claw, its paws are like those of the Dog, and this singular combination of features is in direct relation to its habits, for it does not lie in wait and spring upon its prey like the Cat, but hunts it like the Dog.

SPECIES

THERE remains but one more division of the Animal Kingdom for our consideration, the most limited of all in its circumscription, — that of Species. It is with the study of this kind of group that naturalists generally begin their investigations. I believe, however, that the study of Species as the basis of a scientific education is a great mistake. It leads us to overrate the value of Species, and to believe that they exist in Nature in some different sense from the other groups; as if there were something more real and tangible in Species than in Genera, Families, Orders, Classes,

or Branches. The truth is, that to study a vast number of Species without tracing the principles that combine them under more comprehensive groups is only to burden the mind with disconnected facts, and more may be learned by a faithful and careful comparison of a few Species than by a more cursory examination of a greater number. When one considers the immense number of Species already known, naturalists might well despair of becoming acquainted with them all, were they not constructed on a few fundamental patterns, so that the study of one Species teaches us a great deal for all the rest. De Candolle, who was at the same time a great botanist and a great teacher, told me once that he could undertake to illustrate the fundamental principles of his science with the aid of a dozen plants judiciously selected, and that it was his unvarying practice to induce students to make a thorough study of a few minor groups of plants, in all their relations to one another, rather than to attempt to gain a superficial acquaintance with a large number of species. The powerful influence he has had upon the progress of Botany vouches for the correctness of his views. Indeed, every profound scholar knows that sound learning can be attained only by this method, and the study of Nature makes no exception to the rule.

I would therefore advise every student to select a few representatives from all the Classes, and to study these not only with reference to their spe-

cific characters, but as members also of a Genus, of a Family, of an Order, of a Class, and of a Branch. He will soon convince himself that Species have no more definite and real existence in Nature than all the other divisions of the Animal Kingdom, and that every animal is the representative of its Branch, Class, Order, Family, and Genus as much as of its Species. Specific characters are only those determining size, proportion, color, habits, and relations to surrounding circumstances and external objects. How superficial, then, must be any one's knowledge of an animal who studies it only with relation to its specific characters! He will know nothing of the finish of special parts of the body, — nothing of the relations between its form and its structure, — nothing of the relative complication of its organization as compared with other allied animals, — nothing of the general mode of execution of its structure, — nothing of the general plan of structure expressed in that mode of execution. Yet, with the exception of the ordinal characters, which, since they imply relative superiority and inferiority, require, of course, a number of specimens for comparison, his one animal would tell him all this as well as the specific characters.

All the more comprehensive groups, equally with Species, are based upon a positive, permanent, specific principle, maintained generation after generation with all its essential characteristics. Individuals are the transient representa-

tives of all these organic principles, which certainly have an independent, immaterial existence, since they outlive the individuals that embody them, and are no less real after the generation that has represented them for a time has passed away, than they were before.

From a comparison of a number of well-known Species belonging to a natural Genus, it is not difficult to ascertain what are essentially specific characters. There is hardly among Mammalia a more natural Genus than that which includes the Rabbits and Hares, or that to which the Rats and Mice are referred. Let us see how the different Species differ from one another. Though we give two names in the vernacular to the Genus Hare, both Hares and Rabbits agree in all the structural peculiarities constituting a Genus; but the different Species are distinguished by their absolute size when full-grown, — by the nature and color of their fur, — by the size and form of the ear, — by the relative length of their legs and tail, — by the more or less slender build of their whole body, — by their habits, some living in open grounds, others among the bushes, others in swamps, others burrowing under the earth, — by the number of young they bring forth, — by their different seasons of breeding, — and by still minor differences, such as the permanent color of the hair throughout the year in some, while in others it turns white in winter. The Rats and Mice differ in a similar way: there

being large and small Species, — some gray, some brown, others rust-colored, — some with soft, others with coarse hair; they differ also in the length of the tail, and in having it more or less covered with hair, — in the cut of the ears, and their size, — in the length of their limbs, which are slender and long in some, short and thick in others, — in their various ways of living, — in the different substances on which they feed, — and also in their distribution over the surface of the earth, whether circumscribed within certain limited areas or scattered over a wider range.

What is now the nature of these differences by which we distinguish Species? They are totally distinct from any of the categories on which Genera, Families, Orders, Classes, or Branches are founded, and may readily be reduced to a few heads. They are differences in the proportion of the parts and in the absolute size of the whole animal; in the color and general ornamentation of the surface of the body, and in the relations of the individuals to one another and to the world around. A farther analysis of other Genera would show us that among Birds, Reptiles, Fishes, and, in fact, throughout the Animal Kingdom, Species of well-defined natural Genera differ in the same way. We are therefore justified in saying that the category of characters on which Species are based implies no structural differences, but presents the same structure combined under certain minor differences of size,

proportion, and habits. All the specific characters stand in direct reference to the generic structure, the family form, the ordinal complication of structure, the mode of execution of the Class, and the plan of structure of the Branch, all of which are embodied in the frame of each individual in each Species, even though all these individuals are constantly reproducing others and dying away; so that the specific characters have no more permanency in the individuals than those which characterize the Genus, the Family, the Order, the Class, and the Branch. I believe, therefore, that naturalists have been entirely wrong in considering the more comprehensive groups to be theoretical, and in a measure arbitrary, — that is, an attempt of certain men to classify the Animal Kingdom according to their individual views, — while they have ascribed to Species, as contrasted with the other divisions, a more positive existence in Nature.

No further argument is needed to show that it is not only the Species that lives in the individual, but that every individual, though belonging to a distinct Species, is built upon a precise and definite plan which characterizes its Branch, — that that plan is executed in each individual in a particular way which characterizes its Class, — that every individual with its kindred occupies a definite position in a series of structural complications which characterizes its Order, — that in every individual all these structural features are

combined under a definite pattern of form which characterizes its Family, — that every individual exhibits structural details in the finish of its parts which characterize its Genus, — and finally that every individual presents certain peculiarities in the proportion of its parts, in its color, in its size, in its relations to its fellow-beings and the surrounding objects, which constitute its specific characters; and all this is repeated in the same kind of combination, generation after generation, while the individuals themselves die. If we accept these propositions, which seem to me self-evident, it is impossible to avoid the conclusion that Species do not exist in Nature in any other sense than the more comprehensive groups of the zoölogical system.

A book of Chinese paintings, showing the Golden Carp in its varieties, represents some as short and stout, others long and slender, — some with the ventral side swollen, others hunchbacked, — some with the mouth greatly enlarged, while in others the caudal fin, which, in the normal condition of the Species, is placed vertically at the end of the tail, and is forked like those of other Fishes, has become crested and arched, or is double or crooked, or has swerved in some other way from its original pattern. But, in all these variations,

there is nothing which recalls the characteristic specific differences among the representatives of the Carp Family, which, in their wild state, are very monotonous in their appearance all the world over.

In fact, all the variability among domesticated Species is due to the fostering care, or, in its more extravagant freaks, to the fancies of man; and it has never been observed in the wild Species, where, on the contrary, everything shows the closest adherence to the distinct, well-defined, and invariable limits of the Species. It surely does not follow, that, because the Chinese can, under abnormal conditions, produce a variety of fantastic shapes in the Golden Carp, therefore water, or the physical conditions established in the water, can create a Fish, any more than it follows, that, because they can dwarf a tree, or alter its aspect, by stunting its growth in one direction, and forcing it in another, therefore the earth, or the physical conditions connected with their growth, can create a Pine, an Oak, a Birch, or a Maple.

The common sense of a civilized community has already pointed out the true distinction, in applying another word to the discrimination of the different kinds of domesticated animals. They are called Breeds, and Breeds among animals are the work of man: Species were created by God.

TO REPEAT

Now, as truly as individuals, while they exist, represent their species for the time being and do not constitute them, so truly do these same individuals represent at the same time their genus, their family, their order, their class, and their type, the characters of which they bear as indelibly as those of the species.

As representatives of Species, individual animals bear the closest relations to one another; they exhibit definite relations also to the surrounding elements, and their existence is limited within a definite period.

As representatives of Genera, these same individuals have a definite and specific ultimate structure, identical with that of the representatives of other species.

As representatives of Families, these same individuals have a definite figure, exhibiting, with similar forms of other genera, or for themselves, if the family contains but one genus, a distinct, specific pattern.

As representatives of Orders, these same individuals stand in a definite rank when compared to the representatives of other families.

As representatives of Classes, these same individuals exhibit the plan of structure of their respective types in a special manner, carried out with special means and in special ways.

As representatives of Branches, these same individuals are all organized upon a distinct plan, differing from the plan of other types.

Individuals, then, are the bearers, for the time being, not only of specific characteristics, but of all the natural features in which animal life is displayed in all its diversity.

Viewing individuals in this light, they resume all their dignity; and they are no longer so absorbed in species as to be ever its representatives without being anything for themselves. On the contrary, it becomes plain, from this point of view, that the individual is the worthy bearer, for the time being, of all the riches of nature's wealth of life. This view further teaches us how we may investigate not only the species in the individual, but also the genus, the family, the order, the class, the branch, as indeed naturalists have at all times done in practice, whilst denying the possibility of it in theory.

INDIVIDUALS

Another fact in regard to these animals. Instead of being single, like the Sea-anemone, Corals are generally compound; that is, they multiply without dividing. The successive generations do not become separated from the parent stock, but go on growing attached thereto. We are so familiar with this phenomenon in plants that we hardly notice it. But when we refer to it as a

fact occurring among animals, it strikes us with wonder. The little plant, germinating after throwing out a few leaves for the first year, comes to a stand. It is a little stem with one bud. What is it but an individual grown to that size? The little bud at the head is the next individual, which grows upon the plant the next year. And so on, bud after bud, each of which is an individual growing upon the parent stock, until finally we may have a large tree producing thousands and thousands of buds, no one of which will separate and form a new tree until we cut it off and ingraft it on another plant, which gives us evidence that it is an independent individual. But yet the whole tree is not a single individual, but a community of individuals, growing in close connection and never separating spontaneously. So corals are communities, masses of individuals, growing up in the same way, budding side by side, or dividing in another way, and while dividing or budding or multiplying, remain united together so as to form a larger and larger mass.

Yet, although there is no embryological transition of one type into another, the gradations of growth within the limits of the same type and the same class, already alluded to, are very striking

throughout the Animal Kingdom. There are periods in the development of the germ in the higher members of all the types, when they transiently resemble in their general outline the lower representatives of the same type, just as we have seen that the higher orders of one class pass through stages of development in which they transiently resemble lower orders of the same class. This gradation of growth corresponds to the gradation of rank in adult animals, as established upon comparative complication of structure. For instance, according to their structural character, all naturalists have placed Fishes lowest in the scale of Vertebrates. Now all the higher Vertebrates have a Fish-like character at first, and pass successively through phases in which they vaguely resemble other lower forms of the same type before they assume their own characteristic form; and this is equally true of the other great divisions, so that the history of the individual is, in some sort, the history of its type.

DOMESTICATED ANIMALS

Our domestic animals have always followed man in the progress of civilization. Wherever the traces of civilization are found, there are found also traces of the presence of animals, not only

domesticated, but also wild. No civilization has left us more interesting traces in this respect than that of Egypt; on the Egyptian monuments are represented in sculptures and drawings, and in the catacombs are preserved in the shape of mummies, animals, which lived many thousand years ago. Some of those relics, which have come down to us, are unquestionably nearly five thousand years old. They form a very interesting basis, by which to ascertain to what extent animals may change under the different circumstances in which they live. The most careful comparison which has been made between the skeletons of the animals preserved in mummies, and those recently killed in the valley of the Nile, has not shown the slightest difference between them. We have here, therefore, direct and positive evidence that a period of five thousand years does not change the appearance, character, or structure of any living being.

But there is something more to be considered in regard to domestic animals. They are constantly modified under the fostering care of man, and in a way that is peculiar, — very different from what we observe among the wild animals. This feature should be kept in mind whenever the question of the diversity which we observe in nature is under consideration, — especially since there are those who believe that the varieties we find among our domesticated animals, may afford the clue by which to explain the diversity which exists among wild animals. It is an undoubted fact that the differences among domestic animals, which we designate by the term "breeds," are of comparatively recent date. The

time when many of them were first introduced is known, the variations are the work of man,— the result of human care, of artificial means. But these differences are not of the same kind as the differences we observe among wild animals.

Let us compare some groups of wild animals with the domestic animals to which they evidently belong. There is roving in the Western prairies a wild kind of bull called the Buffalo. It is a distinct species of that family, not yet domesticated. There are different kinds of wild bulls in Africa; on the northernmost part of this continent there is still another kind called the Musk-ox; there is also another kind on the Table-Lands of Asia. All these wild bulls differ from one another in certain ways: either by the character of the hair, the form of the horns, their proportions, size, or color. But all those of one kind are so similar among themselves, that he who has seen one of a herd of Buffalo has seen them all. And the same is the case with the Musk-ox, the Aurochs of Europe, and the Yak of Asia. The animals of each species have a great uniformity among themselves, though they differ widely from those of the other species.

Now examine different breeds. One of the first results of domestication is to introduce an extraordinary diversity among the different individual heads. There are no two heads alike in a herd of domesticated animals. They differ, not only in color and size, but also in the form or twist of the horns. And these differences are only constant as the animals are kept under the same influences. Breeders of cattle know, that, unless they take care of their

herds, all the improvements which domestication has introduced will disappear.

Here, then, we have the evidence that these differences are the work of man, the result of artificial means applied for the purpose of rendering the animals subservient to him; while on the other hand, the differences existing among wild animals are the result of a creative power over which the mind of man has no control. Domesticated animals show us only the amplitude of the pliability of structure in each animal, and in no way the method by which the diversity existing among wild animals can be supposed to have been introduced. Domestication never produces forms which are self-perpetuating, and is therefore in no way an index of the process by which species are produced.

Thus we have two important facts, namely: 1. That a long period of time does not cause differences among animals that are left in their natural condition of existence. 2. That the mind of man alone is capable of producing the extreme differences we observe among the breeds of animals.

GEOGRAPHIC DISTRIBUTION OF ANIMALS AND PLANTS

"My companions and myself have come together so suddenly and so unexpectedly on our present errand, that we have had little time to organize our work. The laying out of a general scheme of operations is, therefore, the first and

one of the most important points to be discussed between us. The time for great discoveries is passed. No student of nature goes out now expecting to find a new world, or looks in the heavens for any new theory of the solar system. The work of the naturalist, in our day, is to explore worlds the existence of which is already known; to investigate, not to discover. The first explorers, in this modern sense, were Humboldt in the physical world, Cuvier in natural history, Lavoisier in chemistry, La Place in astronomy. They have been the pioneers in the kind of scientific work characteristic of our century. We who have chosen Brazil as our field must seek to make ourselves familiar with its physical features, its mountains and its rivers, its animals and plants. There is a change, however, to be introduced in our mode of work, as compared with that of former investigators. When less was known of animals and plants the discovery of new species was the great object. This has been carried too far, and is now almost the lowest kind of scientific work. The discovery of a new species as such does not change a feature in the science of natural history, any more than the discovery of a new asteroid changes the character of the problems to be investigated by astronomers. It is merely adding to the enumeration of objects. We should look rather for the fundamental relations among animals; the number of species we may find is of importance only so far as they explain the distribution and limitation of different genera and families, their relations to each other and to the physical conditions under which they live. Out of such investigations there looms up a deeper question for scientific men, the solution of which is to be the most important result of their work in coming generations. The origin of life is the great question of the day. How did the organic world come to be as it is? It must be our aim to throw some light on this subject by our present journey. How did Brazil come to be inhabited by the

animals and plants now living there? Who were its inhabitants in past times? What reason is there to believe that the present condition of things in this country is in any sense derived from the past? The first step in this investigation must be to ascertain the geographical distribution of the present animals and plants. Suppose we first examine the Rio San Francisco. The basin of this river is entirely isolated. Are its inhabitants, like its waters, completely distinct from those of other basins? Are its species peculiar to itself, and not repeated in any other river of the continent? Extraordinary as this result would seem, I nevertheless expect to find it so. The next water-basin we shall have to examine will be that of the Amazons, which connects through the Rio Negro with the Orinoco. It has been frequently repeated that the same species of fish exist in the waters of the San Francisco and in those of Guiana and of the Amazons. At all events, our works on fishes constantly indicate Brazil and Guiana as the common home of many species; but this observation has never been made with sufficient accuracy to merit confidence. Fifty years ago the exact locality from which any animal came seemed an unimportant fact in its scientific history, for the bearing of this question on that of origin was not then perceived. To say that any specimen came from South America was quite enough; to specify that it came from Brazil, from the Amazons, the San Francisco, or the La Plata, seemed a marvellous accuracy in the observers. In the museum at Paris, for instance, there are many specimens entered as coming from New York or from Pará; but all that is absolutely known about them is that they were shipped from those sea-ports. Nobody knows exactly where they were collected. So there are specimens entered as coming from the Rio San Francisco, but it is by no means sure that they came exclusively from that water-basin. All this kind of investigation is far too

loose for our present object. Our work must be done with much more precision; it must tell something positive of the geographical distribution of animals in Brazil. Therefore, my young friends who come with me on this expedition, let us be careful that every specimen has a label, recording locality and date, so secured that it shall reach Cambridge safely. It would be still better to attach two labels to each specimen, so that, if any mischance happens to one, our record may not be lost. We must try not to mix the fishes of different rivers, even though they flow into each other, but to keep our collections perfectly distinct. You will easily see the vast importance of thus ascertaining the limitation of species, and the bearing of the result on the great question of origin.

"Something is already known. It is ascertained that the South American rivers possess some fishes peculiar to them. Were these fishes then created in these separate water-systems as they now exist, or have they been transferred thither from some other water-bed? If not born there, how did they come there? Is there, or has there ever been, any possible connection between these water-systems? Are their characteristic species repeated elsewhere? Thus we narrow the boundaries of the investigation, and bring it, by successive approaches, nearer the ultimate question. But the first inquiry is, How far are species distinct all over the world, and what are their limits? Till this is ascertained, all theories about their origin, their derivation from one another, their successive transformation, their migration from given centres, and so on, are mere beating about the bush. I allude especially to the fresh-water fishes, in connection with this investigation, on account of the precision of their boundaries. Looking at the matter theoretically, without a positive investigation, I do not expect to find a single species of the Lower Amazons

above Tabatinga.* I base this supposition upon my own observations respecting the distribution of species in the European rivers. I have found that, while some species occur simultaneously in the many upper water-courses which combine to form the Rhine, the Rhone, and the Danube, most of them are not found in the lower course of these rivers; that, again, certain species are found in two of these water-basins and do not occur in the third, or inhabit only one and are not to be met in the two others. The brook trout, for instance (*Salmo Fario*), is common to the upper course and the higher tributaries of all the three river-systems, but does not inhabit the main bed of their lower course. So it is, also, and in a more striking degree, with the Salmling (*Salmo Salvelinus*). The Huchen (*Salmo Hucho*) is only found in the Danube. But the distribution of the perch family in these rivers is, perhaps, the most remarkable. The Zingel (*Aspro Zingel*) and the Schrætzer (*Acerina Schrœtzer*) are only found in the Danube; while *Acerina cernua* is found in the Danube as well as in the Rhine, but not in the Rhone; and *Aspro asper* in the Danube as well as in the Rhone, but not in the Rhine. The Sander (*Lucioperca Sandra*) is found in the Danube and the other large rivers of Eastern Europe, but occurs neither in the Rhine nor in the Rhone. The common perch (*Perca fluviatilis*), on the contrary, is found both in the Rhine and Rhone, but not in the Danube, which, however, nourishes another species of true Perca, already described by Schaeffer

* This anticipation was more than confirmed by the result of the journey. It is true that Mr. Agassiz did not go beyond the Peruvian frontier, and therefore could not verify his prophecy in that region. But he found the localization of species in the Amazons circumscribed within much narrower limits than he expected, the whole length of the great stream, as well as its tributaries, being broken up into numerous distinct faunæ. There can be no doubt that what is true for nearly three thousand miles of its course is true also for the head-waters of the Amazons; indeed, other investigators have already described some species from its higher tributaries differing entirely from those collected upon this expedition.

as *Perca vulgaris*. Again, the pickerel (*Esox Lucius*) is common to all these rivers, especially in their lower course, and so is also the cusk (*Lota vulgaris*). The special distribution of the carp family would afford many other striking examples, but they are too numerous and too little known to be used as an illustration here.

"This is among the most remarkable instances of what I would call the arbitrary character of geographical distribution. Such facts cannot be explained by any theory of accidental dispersion, for the upper mountain rivulets, in which these great rivers take their rise, have no connection with each other; nor can any local circumstance explain the presence of some species in all the three basins, while others appear only in one, or perhaps in two, and are absent from the third, or the fact that certain species inhabiting the head-waters of these streams are never found in their lower course when the descent would seem so natural and so easy. In the absence of any positive explanation, we are left to assume that the distribution of animal life has primary laws as definite and precise as those which govern anything else in the system of the universe."

ALTERNATE GENERATIONS

This alternate generation differs essentially from metamorphosis, though some writers have attempted to identify these two processes. In metamorphosis, as observed among Insects, the individual born from an egg goes on undergoing change after change in direct and immediate succession, until it has reached its final transformation; but, however different it may be at different periods of its life,

it is always one and the same individual. In alternate generations, the individual born from an egg never assumes through a succession of transformations the character of its parent, but produces, either by internal or external budding or by division, a number—sometimes even a large number—of new individuals, and it is this progeny of the individuals born from eggs which grows and assumes again the characters of the egg-laying individuals.

ALTERNATE GENERATIONS AND TRANSMUTATION

On the way to Brazil Agassiz gave a little history of Steenstrup and Sars, and showed the influence their embryological investigations have had in reforming classification, and also their direct bearing upon the question of the origin of species. To these investigators science owes the discovery of the so-called "alternate generations," in which the Hydroid, either by budding or by the breaking up of its own body, gives rise to numerous jelly-fishes; these lay eggs which produce Hydroids again, and the Hydroids renew the process as before.*

"These results are but recently added to the annals of sci-

* As these investigations have been published with so much detail (Steenstrup, Alternate Generation, Sars's Fauna Norwegica; L. Agassiz, Contr. to Nat. Hist. of U. S.), it has not been thought necessary to reproduce this part of the lecture here. Any one who cares to read a less technical account of these investigations than those originally published, will find it in "Methods of Study," by L. Agassiz.

ence and are not yet very extensively known in the community; but when the facts are more fully understood, they cannot fail to affect the fundamental principles of zoölogy I have been astonished to see how little weight Darwin himself gives to this series of transformations; he hardly alludes to it, and yet it has a very direct bearing on his theory, since it shows that, however great the divergence from the starting-point in any process of development, it ever returns to the road of its normal destiny; the cycle may be wide, but the boundaries are as impassable as if it were narrower. However these processes of development may approach, or even cross each other, they never end in making any living being different from the one which gave it birth, though in reaching that point it may pass through phases resembling other animals.

"In considering these questions we should remember how slight are most of those specific differences, the origin of which gives rise to so much controversy, in comparison with the cycle of changes undergone by every individual in the course of its development. There are numerous genera, including many very closely allied species, distinguished by differences which, were it not for the fact that they have remained unchanged and invariable through ages, might be termed insignificant. Such, for instance, are the various species of corals found in the everglades of Florida, where they lived and died ages ago, and had the identical specific differences by which we distinguish their successors in the present Florida reefs. The whole science of zoölogy in its present condition is based upon the fact that these slight differences are maintained generation after generation. And yet every individual on such a coral stock, — and the same is true of any individual in any class whatsoever of the whole animal kingdom, whether Radiate, Mollusk, Articulate, or Vertebrate, — before reaching its adult condition and assuming the permanent characters which dis-

tinguish it from other species, and have never been known to vary, passes in a comparatively short period through an extraordinary transformation, the successive phases of which differ far more from each other than do the adult species. In other words, the same individual differs more from himself in successive stages of his growth than he does in his adult condition from kindred species of the same genus. The conclusion seems inevitable, that, if the slight differences which distinguish species were not inherent, and if the phases through which every individual has to pass were not the appointed means to reach that end, themselves invariable, there would be ever-recurring deviations from the normal types. Every naturalist knows that this is not the case. All the deviations known to us are monstrosities, and the occurrence of these, under disturbing influences, are to my mind only additional evidence of the fixity of species. The extreme deviations obtained in domesticity are secured, as is well known, at the expense of the typical characters, and end usually in the production of sterile individuals. All such facts seem to show that so-called varieties or breeds, far from indicating the beginning of new types, or the initiating of incipient species, only point out the range of flexibility in types which in their essence are invariable.

"In the discussion of the development theory in its present form, a great deal is said of the imperfection of the geological record. But it seems to me that, however fragmentary our knowledge of geology, its incompleteness does not invalidate certain important points in the evidence. It is well known that the crust of our earth is divided into a number of layers, all of which contain the remains of distinct populations. These different sets of inhabitants who have possessed the earth at successive periods have each a character of their own. The transmutation theory insists that they owe their origin to gradual transformations, and are not, therefore, the result of distinct creative acts.

All agree, however, that we arrive at a lower stratum where no trace of life is to be found. Place it where we will: suppose that we are mistaken in thinking that we have reached the beginning of life with the lowest Cambrian deposit; suppose that the first animals preceded this epoch, and that there was an earlier epoch, to be called the Laurentian system, beside many others older still; it is nevertheless true that geology brings us down to a level at which the character of the earth's crust made organic life impossible. At this point, wherever we place it, the origin of animals by development was impossible, because they had no ancestors. This is the true starting-point, and until we have some facts to prove that the power, whatever it was, which originated the first animals has ceased to act, I see no reason for referring the origin of life to any other cause. I grant that we have no such evidence of an active creative power as Science requires for positive demonstration of her laws, and that we cannot explain the processes which lie at the origin of life. But if the facts are insufficient on our side, they are absolutely wanting on the other. We cannot certainly consider the development theory proved, because a few naturalists think it plausible: it seems plausible only to the few, and it is demonstrated by none. I bring this subject before you now, not to urge upon you this or that theory, strong as my own convictions are: I wish only to warn you, not against the development theory itself, but against the looseness in the methods of study upon which it is based. Whatever be your ultimate opinions on this subject, let them rest on facts and not on arguments, however plausible. This is not a question to be argued, it is one to be investigated."

LETTER TO A. SEDGWICK

ON FIXITY OF SPECIES

I find it impossible to attribute the biological phenomena, which have been and still are going on upon the surface of our globe, to the simple action of physical forces. I believe they are due, in their entirety, as well as individually, to the direct intervention of a creative power, acting freely and in an autonomic way. . . . I have tried to make this intentional plan in the organization of the animal kingdom evident, by showing that the differences between animals do not constitute a material chain, analogous to a series of physical phenomena, bound together by the same law, but present themselves rather as the phases of a thought, formulated according to a definite aim. I think we know enough of comparative anatomy to abandon forever the idea of the transformation of the organs of one type into those of another. The metamorphoses of certain animals, and especially of insects, so

often cited in support of this idea, prove, by the fixity with which they repeat themselves in innumerable species, exactly the contrary. In the persistency of these metamorphoses, distinct for each species and known to repeat themselves annually in a hundred thousand species, and to have done so ever since the present order of things was established on the earth, have we not the most direct proof that the diversity of types is not due to external natural influences? I have followed this idea in all the types of the animal kingdom. I have also tried to show the direct intervention of a creative power in the geographical distribution of organized beings on the surface of the globe when the species are definitely circumscribed. As evidence of the fixity of generic types and the existence of a higher and free causal power, I have made use of a method which appears to me new as a process of reasoning. The series of reptiles, for instance, in the family of lizards, shows apodal forms, forms with rudimentary feet, then with a successively larger number of fingers until we reach, by seemingly insensible gradations, the genera Anguis, Ophisaurus, and Pseudopus, the Chamosauria, Chirotes, Bipes, Sepo, Scincus, and at last the true lizards. It would

seem to any reasonable man that these types are the transformations of a single primitive type, so closely do the modifications approach each other; and yet I now reject any such supposition, and after having studied the facts most thoroughly, I find in them a direct proof of the creation of all these species. It must not be forgotten that the genus Anguis belongs to Europe, the Ophisaurus to North America, the Pseudopus to Dalmatia and the Caspian steppe, the Sepo to Italy, etc. Now, I ask how portions of the earth so absolutely distinct could have combined to form a continuous zoölogical series, now so strikingly distributed, and whether the idea of this development could have started from any other source than a creative purpose manifested in space? These same purposes, this same constancy in the employment of means toward a final end, may be read still more clearly in the study of the fossils of the different creations. The species of all the creations are materially and genealogically as distinct from each other as those of the different points on the surface of the globe. I have compared hundreds of species reputed identical in various successive deposits, — species which are always quoted in favor of a transition, however indirect, from

one group of species to another, — and I have always found marked specific differences between them. In a few weeks I will send you a paper which I have just printed on this subject, where it seems to me this view is very satisfactorily proved. The idea of a procreation of new species by preceding ones is a gratuitous supposition opposed to all sound physiological notions. And yet it is true that, taken as a whole, there is a gradation in the organized beings of successive geological formations, and that the end and aim of this development is the appearance of man. But this serial connection of all successive creatures is not material; taken singly these groups of species show no relation through intermediate forms genetically derived one from the other. The connection between them becomes evident only when they are considered as a whole emanating from a creative power, the author of them all.

GLACIERS

Just as the investigation of the ice-period in the United States has shown us

that ice-fields may move over open level plains, as well as along the slopes of mountain valleys, so does a study of the same class of facts in South America reveal new and unlooked-for features in the history of the ice-period. Some will say, that the fact of the advance of ice-fields over an open country is by no means established, inasmuch as many geologists believe all the so-called glacial traces, namely, striæ, furrows, polish, etc., found in the United States, to have been made by floating icebergs at a time when the continent was submerged. To this I can only answer, that in the State of Maine I have followed, compass in hand, the same set of furrows, running from north to south in one unvarying line, over a surface of one hundred and thirty miles from the Katahdin Iron Range to the sea-shore. These furrows follow all the inequalities of the country, ascending ranges of hills varying from twelve to fifteen hundred feet in height, and descending into the intervening valleys only two or three hundred feet above the sea, or sometimes even on a level with it. I take it to be impossible that a floating mass of ice should travel onward in one rectilinear direction, turning neither to the right nor to the left, for such a distance. Equally impossible would it be for a detached mass of ice, swimming on the sur-

face of the water, or even with its base sunk considerably below it, to furrow in a straight line the summits and sides of the hills, and the beds of the valleys. It would be carried over the depressions without touching bottom. Instead of ascending the mountains, it would remain stranded against any elevation which rose greatly above its own basis, and, if caught between two parallel ridges, would float up and down between them. Moreover, the action of solid, unbroken ice, moving over the ground in immediate contact with it, is so different from that of floating ice-rafts or icebergs, that, though the latter have unquestionably dropped erratic boulders, and made furrows and striæ on the surface where they happened to be grounded, these phenomena will easily be distinguished from the more connected traces of glaciers, or extensive sheets of ice, resting directly upon the face of the country and advancing over it. There seems to be an inextricable confusion, in the ideas of many geologists, as to the respective action of currents, icebergs, and glaciers. The facts connected with these phenomena are in truth very different from each other, and easily recognized after the discrimination has once been made. As to the southward movement of an immense field of ice extending over the whole

north, it seems inevitable, the moment we admit that snow may accumulate around the pole in such quantities as to initiate a pressure radiating in every direction. Snow alternately thawing and freezing must, like water, find its level at last. A sheet of snow ten or fifteen thousand feet in thickness, extending all over the northern and southern portions of the globe, must necessarily lead, in the end, to the formation of a northern and southern cap of ice, moving toward the equator.

I may say, without exaggeration, that glacial phenomena extend over the whole length and breadth of the State of Maine, wherever there is no obvious cause for their disappearance. One word of explanation, that this assertion of their omnipresence may not seem overdrawn to those who follow me over the same ground, expecting, perhaps, to find the glacial writing at every step along the roadside, and to see the polished surfaces as shining and slippery as a metallic plate or a marble slab. In the first place, all kinds of rock

do not admit the same degree of polish. Coarse and friable sandstone cannot be polished under any circumstances. Only the finer granitic rocks retain the striæ and the polished surfaces very distinctly, in this region; and even upon these they are frequently hidden by the accumulation of soil, or occasionally obliterated by decay, where the rock is not hard enough to resist the atmospheric influences. The loose materials themselves, which have served as emery to grind down, polish, and groove the surface of the soil, may eventually become a screen to cover it from observation. The skill of the geologist consists in tracing these marks from spot to spot over surfaces where they were once continuous. When I say that I followed the glacial marks, compass in hand, from north to south, over a line a hundred miles in length, I do not mean that I never lost sight of them for that distance; but simply that one set of lines, which always ran due north and south, unless deflected as we shall see by some local cause usually explicable on the spot, might be traced at intervals over all the rocky surfaces. If they disappeared under a stream on its northern shore, they reappeared on the southern side; if hidden for a time by some mass of vegetation, they were found again farther on; and thus —

allowing for natural and inevitable interruptions — it may be correctly said that they are continuous over the whole country. The glaciated surfaces — to express in one word the combined action of glaciers on the rocks over which they move — present the most varied outlines, sometimes flat, sometimes bulging, with inclined slopes. But whether more or less prominent, they are always rounded, dome-shaped, and the larger furrows, like the smaller striæ and grooves, are invariably straight. Never do we find winding, branching furrows determined by the inequalities in the hardness of the rock, or by pre-existing fissures, as is the case wherever rocks are worn by water, or rather by sand and pebbles set in motion by water.

This region is literally strewn with huge boulders, sometimes forty or fifty feet high. For the most part they seem to belong to the neighboring hills, and have not travelled a great distance. There are many of these boulders, however, which add their testimony to

show that the path of the great ice-plough has been from north to south. This is especially the case with the granite rock of Dedham, so well characterized by its large feldspar crystals, detached masses of which are frequently found to the south of that locality, but never to the north of it. Occasional boulders of a much more northern origin are not wanting. Another link in the evidence is that, wherever the marks are preserved on any abruptly rising ground, they occur on its northern side, and do not appear on the southern one. Evidently the abrading agent advanced from the north, pushed up and over the face presented to it, while the southern face was comparatively protected, the rigid mass no doubt often bridging the opposite declivity without even touching it. I suppose these facts, which perhaps seem insignificant in themselves, must be far less expressive to the general observer than to one who has seen this whole set of phenomena in active operation. To me they have been for many years so familiar in the Alpine valleys, and their aspect in those regions is so identical with the facts above described, that, paradoxical as the statement may seem, the presence of the ice is now an unimportant element to me in the study of glacial phenomena. It is no more essential to the

investigator who has once seen its connection with the facts, than is the flesh which once clothed it to the anatomist who studies the skeleton of a fossil animal. In the face of these facts it seems preposterous to assume that the loose materials and boulders scattered over this interval should have been stranded by icebergs driven inward from the sea-shore by currents or tidal waves. The whole movement, whatever its cause, was unquestionably in the opposite direction. The testimony of the loose materials and erratic boulders is the same all over the United States. They are always of northern birth. I have never seen a single fragment of rock from any more southern locality resting upon glaciated surfaces to the north of them, though I have searched for them from the Atlantic coast to Iowa.

One naturally asks, What was the use of this great engine set at work ages ago to grind, furrow, and knead over, as it were, the surface of the earth? We have our answer in the fertile soil which spreads over the temperate regions of the globe. The glacier was

God's great plough; and when the ice vanished from the face of the land, it left it prepared for the hand of the husbandman. The hard surface of the rocks was ground to powder, the elements of the soil were mingled in fair proportions, granite was carried into the lime regions, lime was mingled with the more arid and unproductive granite districts, and a soil was prepared fit for the agricultural uses of man. I have been asked whether this inference was not inconsistent with the fact that a rich vegetation preceded the ice-period, — a vegetation sufficiently abundant to sustain the tropical animals then living throughout the temperate regions. But the vegetation which has succeeded the ice-period is of a different character, and one that could not have flourished on a soil that would nourish a more tropical growth. The soil we have now over the temperate zone is a grain-growing soil, — one especially adapted to those plants most necessary to the higher domestic and social organizations of the human race. Therefore I think we may believe that God did not shroud the world he had made in snow and ice without a purpose, and that this, like many other operations of his providence, seemingly destructive and chaotic in its first effects, is nevertheless a work of beneficence and order.

ASPECTS OF INTELLIGENCE

"RIPENING OF LEAVES"

It was late in September, just at the turn of the leaf; the woods were in all their golden and crimson glory, with here and there a purple beech, or a background of dark green pines. Familiar as we all are with the brilliancy of the autumnal foliage in the neighborhood of our towns, one must see it in the unbroken forest, covering the country with rainbow hues as far as the eye can reach, in order to appreciate fully its wonderful beauty. A few words on this change of color, which is as constant as any other botanical character (each kind of tree having its special tints peculiar to itself, and not reproduced by other kinds), may not be amiss. Indeed, not only does every species have its appointed range of color, but each individual tree has its history told more or less distinctly in the ripening of the foliage. A weaker or a younger limb may have put on its autumn garb, and be almost ready to drop its leaves, while the rest of the tree is untouched. A single scarlet maple or red oak often gives us the most beautiful arrangement of tints, from the green of mid-

summer, through every shade of orange and red; in the same way one leaf may ripen unequally, its green surface being barred or spotted with crimson or gold for days before the whole leaf turns. These differences give ample opportunity for studying the ripening process. In attempting to determine the cause of these changes, it ought not to be forgotten that they occur locally, and also make their appearance on particular trees much earlier than upon others; so early, indeed, as to show clearly the fallacy of the prevalent idea that they are caused by frost. The temperature remains ten or fifteen degrees above the freezing-point for a month and more after a good many of our trees have assumed their bright autumnal hues. The process is, no doubt, akin to that of ripening in fruits; especially in such fleshy fruits as turn from green to yellow, purple, or red, like apples, peaches, plums, cherries, and others. The change in color coincides with changes in the constitutive chemical elements of the plant; and this comparison between the ripening of foliage and fruit seems the more natural, when we remember that fruits are but a modification of leaves, assuming higher functions and special adaptations in the flower, so as to produce what we call a fruit. The ripening process by

which the leaves take on their final colors is as constant and special as in the fruits. The cherries do not assume their various shades of red, deepening sometimes into black, or the plums their purples, or the peaches their velvety-rose tints, or the apples their greens, russets, browns, and reds, with more unvarying accuracy than the different kinds of maples and oaks, or the beeches, birches, and ashes, take on their characteristic tints. The inequality of the ripening of the foliage alluded to above has also its counterpart in the fruits. Here and there a single apple or peach or pear ripens prematurely, while all the rest of the fruit remains green, or a separate branch brings its harvest to maturity in advance of all the surrounding branches. No doubt the brilliancy of the change in the United States, as compared with other countries, is partly due to the dryness of the climate; and indeed it has been observed that certain European flowers take on deeper hues when transplanted to America. But I believe the cause lies rather in the special character of certain American plants and trees. The Virginia-creeper, for instance, which is much cultivated now in France and Germany, turns to as brilliant a scarlet in a European garden as in its native woods.

PHYLLOTAXIS

The palms, as a natural group, stand out among all other plants with remarkable distinctness and individuality. And yet this common character, uniting them so closely as a natural order, does not prevent the most striking difference between various kinds of palms. As a whole, no family of trees is more similar; generically and specifically none is more varied, even though other families include a greater number of species. Their differences seem to me to be determined in a great measure by the peculiar arrangement of their leaves; indeed, palms, with their colossal leaves, few in number, may be considered as ornamental diagrams of the primary laws according to which the leaves of all plants throughout the whole vegetable kingdom are arranged; laws now recognized by the most advanced botanists of the day, and designated by them as Phyllotaxis.[1] The simplest arrangement in these mathematics of the vegetable world is that of the grasses, in which the leaves are placed alternately on opposite sides of the stem, thus dividing the space around it in equal halves. As the stem of the grasses elongates, these pairs of leaves are found scattered along its length; and it is only in ears or spikes of some genera that we find them growing so compactly on the axis as to form a close head. Of this law of growth the palm known as the Baccába of Pará (Œnocarpus distychius) is an admirable

[1] Botany owes to Alexander Braun and Karl Schimper the discovery of this law, by which leaves, however crowded, are so arranged around the stem as to divide the space with mathematical precision, thus giving to each leaf its fair share of room for growth.

illustration; its leaves being disposed in pairs one above another at the summit of the stem, but in such immediate contact as to form a thick crown. On account of this disposition of the leaves, its appearance is totally different from that of any other palm with which I am acquainted. I do

Fan Baccába (Œnocarpus distychius).

not know any palm in which the leaves are arranged in three directions only, as in the reeds and sedges of our marshes, unless it be the Jacitara (Desmonchus), whose winding slender stem, however, makes the observation uncertain. An arrangement in five different directions is common in all those palms which, when young, have only a cluster of five fully developed leaves above the ground, with a spade-like sixth leaf rising from the centre. When

full grown, they usually exhibit a crown of ten or fifteen leaves and more, divided into tiers of five, one above the other, but so close together that the whole appears like a rounded head. Sometimes, however, the crown is more open, as in the Maximiliana regia (Inaja), for instance, in which the stem is not very high, and the leaves, always in cycles of five, spread slightly, so as to form an open vase rising from a slender stem. The Assai (Euterpe edulis) has an eight-leaved arrangement, and has never more than a single cycle of leaves, though it may sometimes have seven leaves when the first of the old cycle has dropped, before the ninth, with which the new cycle begins, has opened; or nine, if the first leaf of the new cycle (the ninth in number) has opened, before the first of the old cycle has dropped. These leaves, of a delicate, pale green, are cut into a thousand leaflets, which tremble in the lightest breeze, and tell you that the air is stirring even when the heat seems breathless. A more elegant and attractive diagram of the Phyllotaxis of $\frac{3}{8}$ probably does not exist in nature. The common Cocoa-nut tree has its leaves arranged according to the fraction of $\frac{5}{13}$; but, though the crown consists of several cycles of leaves, they do not form a close head, because the older ones become pendent, while the younger are more erect. The Pupunha, or peach palm (Guilielma), follows the Phyllotaxis of $\frac{8}{21}$; but in this instance all the leaves are evenly arched over, so that the whole forms a deep-green vault, the more beautiful from the rich color of the foliage. When the heavy cluster of ripe, red fruit hangs under this dark vault, the tree is in its greatest beauty. As the leaves of this palm are not so closely set in the younger specimens as in the older ones, its aspect changes at different stages of growth; the leaves in the younger trees being distributed over a greater length of the trunk, while, in the adult taller ones, they are more compact. This arrangement is repeated in the Javari and Tucuma (Astrocaryum); but in these the

closely-set leaves stand erect, broom-like, at the head of the long stalk. In the Mucaja (Acrocomia) the leaves are arranged according to the fraction $\frac{1}{3}\frac{3}{4}$. Thus, under the same fundamental principle of growth, an infinite variety is introduced, among trees of one order, by the slight differences in the distribution and constitution of the leaves themselves. In the Musaceæ, or Scytamineæ, the Bananas, another order of the same class of plants, a diversity equally remarkable is produced in the same way, namely, by slight modifications of this fundamental law. What can differ more in appearance than the common Banana (Musa paradisiaca), with its large simple leaves, so loosely arranged around the stem, so graceful and easy in their movements, and the Banana of Madagascar (Ravenala madagascariensis), commonly known as the Traveller's tree, which, like the Baccába of Pará, has its leaves alternating regularly on opposite sides of the trunk, and so closely packed together as to form an immense flat fan on a colossal stem? Yet, in all these plants the arrangement of leaves obeys the same law, which is illustrated with equal distinctness by each one. This mathematical disposition of leaves is thus shown to be compatible with a great variety of essentially different structures; and though the law of Phyllotaxis prevails in all plants, being limited neither to class, orders, families, genera, nor species, but running in various combinations through the whole kingdom, I believe it can be studied to especial advantage in the group of palms, on account of the prominence of their few large leaves.

. . . As soon as we reached the Gulf Stream we began work. Indeed, Pourtalès had organized a party to study the temperatures as soon as we passed Gay Head, and will himself report to you his results. My own attention was entirely turned to the Gulf weed and its inhabitants, of which we made extensive collections. Our observations on the floating weed itself favor the view of those who believe it to be torn from rocks, on which Sargassum naturally grows. I made a simple experiment which seems to me conclusive. Any branch of the sea-weed which is deprived of its *floats* sinks at once to the bottom of the water, and these floats are not likely to be the first parts developed from the spores. Moreover, after examining large quantities of the weed, I have not seen a single branch, however small, which did not show marks of having been torn from a solid attachment.

You may hardly feel an interest in my zoological observations, but I am sure you will be glad to learn that we had the best opportunity of carefully examining most of the animals known to inhabit the Gulf weed, and some also which I did not know to occur

among them. The most interesting discovery of our voyage thus far, however, is that of a nest built by a fish, and floating on the broad ocean with its living freight. On the 13th, Mr. Mansfield, one of our officers, brought me a ball of Gulf weed which he had just picked up, and which excited my curiosity to the utmost. It was a round mass of Sargassum about the size of two fists. The bulk of the ball was made up of closely packed branches and leaves, held together by fine threads, running through them in every direction, while other branches hung more loosely from the margin. Placed in a large bowl of water it became apparent that the loose branches served to keep the central mass floating, cradle-like, between them. The elastic threads, which held the ball of Gulf weed together, were beaded at intervals, sometimes two or three beads close together, or a bunch of them hanging from the same cluster of threads, or occasionally scattered at a greater distance from each other. Nowhere was there much regularity in the distribution of the beads. They were scattered pretty uniformly throughout the whole ball of sea-weed, and were themselves about the size of an ordinary pin's head. Evidently we had before us a nest of

the most curious kind, full of eggs. What animal could have built this singular nest? It did not take long to ascertain the class to which it belonged. A common pocket lens revealed at once two large eyes on the side of the head, and a tail bent over the back of the body, as in the embryo of ordinary fishes shortly before the period of hatching. The many empty egg cases in the nest gave promise of an early opportunity of seeing some embryos, freeing themselves from their envelope. Meanwhile a number of these eggs containing live embryos were cut out of the nest and placed in separate glass jars, in order to multiply the chances of preserving them; while the nest as a whole was secured in alcohol, as a memorial of our discovery.

The next day I found two embryos in my glass jars; they moved occasionally in jerks, and then rested a long time motionless on the bottom of the jar. On the third day [illegible]nd over a dozen of these young fishes, the oldest beginning to be more active. I need not relate in detail the evidence I soon obtained that these embryos were actually fishes. . . . But what kind of fish was it? At about the time of hatching, the fins differ too much from those of the adult, and the general form

has too few peculiarities, to give any clew to this problem. I could only suppose it would prove to be one of the pelagic species of the Atlantic. In former years I had made a careful study of the pigment cells of the skin in a variety of young fishes, and I now resorted to this method to identify my embryos. Happily we had on board several pelagic fishes alive. The very first comparison I made gave the desired result. The pigment cell of a young Chironectes pictus proved identical with those of our little embryos. It thus stands, as a well authenticated fact, that the common pelagic Chironectes of the Atlantic, named Ch. pictus by Cuvier, builds a nest for its eggs in which the progeny is wrapped up with the materials of which the nest itself is composed; and as these materials consist of the living Gulf weed, the fish cradle, rocking upon the deep ocean, is carried along as in an arbor, which affords protection and afterwards food also, to its living freight. This marvelous story acquires additional interest, when we consider the characteristic peculiarities of the genus Chironectes. As its name indicates, it has fin-like hands; that is to say, the pectoral fins are supported by a kind of long wrist-like appendage, and the rays of the ventrals are

not unlike rude fingers. With these limbs these fishes have long been known to attach themselves to sea-weeds, and rather to walk than to swim in their natural element. But now that we know their mode of reproduction, it may fairly be asked if the most important use of their peculiarly constructed fins is not the building of their nest? . . . There thus remains one closing chapter to the story. May some naturalist, becalmed among the Gulf weed, have the good fortune to witness the process by which the nest is built. . . .

AFFECTION

This class includes animals of various degrees of complication of structure, from those with highly developed organizations to the Worms that float in fresh water like long hairs and hardly seem to be animals, and to those still lower representatives of the class that live in the cavities of other animals. Yet even creatures so low in the scale of life as the Gordius, that long thread-like Worm found often in brooks and called Horsehair by the common people, are not devoid of some instincts, however dim, of feeling and affection. I remember a case in

point, that excited my own wonder at the time, and may not be uninteresting to my readers.

I had received from Detroit, through the kindness of Messrs. Higby and Stearns, one of these singular animals. When I first saw it, it was coiled up in a close roll at the bottom of a bottle filled with fresh water, and looked more like a little tangle of black sewing-silk than anything else. Wishing to unwind it, that I might examine its entire length, I placed it in a large china basin filled with water, and proceeded very gently to disentangle its coils, when I perceived that the animal had twisted itself around a bundle of its eggs, holding them fast in a close embrace. In the process of unwinding, the eggs dropped away and floated to a little distance. Having finally stretched it out to its full length, perhaps half a yard, I sat watching to see if this singular being that looked like a long black thread in the water would give any signs of life. Almost immediately it moved towards the bundle of eggs, and, having reached it, began to sew itself through and through the little white mass, passing one end of its body through it, and then returning to make another stitch, as it were, till the eggs were at last completely entangled again in an intricate network of coils.

It seemed to me almost impossible that this care of offspring could be the result of any instinct of affection in a creature of so low an organization, and I again separated it from the

eggs, and placed them at a greater distance, when the same action was repeated. On trying the experiment a third time, the bundle of eggs had become loosened, and a few of them dropped off singly into the water. The efforts which the animal then made to recover the missing ones, winding itself round and round them, but failing to bring them into the fold with the rest, because they were too small and evaded all efforts to secure them when once parted from the first little compact mass, convinced me that there was a definite purpose in its attempts, and that even a being so low in the scale of animal existence has some dim consciousness of a relation to its offspring.

I afterwards unwound the mass of eggs, which, when coiled up as I first saw it, made a roll of white substance about the size of a coffee-bean, and found that it consisted of a string of eggs, measuring more than twelve feet in length, the eggs being held together by some gelatinous substance that cemented them and prevented them from falling apart. Cutting this string across, and placing a small section under the microscope, I counted on one surface of such a cut from seventy to seventy-five eggs; and, estimating the entire number of eggs according to the number contained on such a surface, I found that there were not less than eight millions of eggs in the whole string. The fertility of these lower animals is truly amazing, and is no doubt

a provision of Nature against the many chances of destruction to which these germs, so delicate and often microscopically small, must be exposed. The higher we rise in the Animal Kingdom, the more limited do we find the number of progeny, and the care bestowed upon them by the parents is in proportion to this diminution.

The subsequent adventures of these germs form so odd a sequel to their early history, that I will add it here. The eggs are hatched in the water, the embryos first making their appearance as little transparent bodies, moving about by means of verbratile cilia. Their only appendages are minute horns attached to one end of the body. Strange to say, their next step in life is to creep into the legs of grasshoppers and burrow their way into the abdominal cavity of these animals, where they undergo their further development as Worms, sometimes growing to be two or three inches in length before they are freed. When they have grown so large that the grasshopper becomes distended by the size of its strange inhabitant, it bursts, the Worm is released, and returns to its aquatic life. When familiar with the vicissitudes in the life of these animals, one ceases to wonder that Nature should make large provision against the many chances of destruction that beset them, and one may readily believe, that, of the eight millions of eggs born from one individual, a comparatively small number survive.

Who, for instance, could believe for a moment longer that the habits of animals are in any degree determined by the circumstances under which they live, after having seen a little turtle of the genus Chelydra, still enclosed in its egg-shell, which it hardly fills half-way, with a yolk bag as large as itself hanging from its lower surface and enveloped in its amnios and in its allantois, with the eyes shut, snapping as fiercely as if it could bite without killing itself?

RADIATES

We will first compare the three Orders of Acalephs, among which the Hydroids stand lowest, the Discophoræ next, and the Ctenophoræ highest. The fact that these animals have no popular names shows how little they are known. It is true that we hear some of them spoken of as Jelly-Fishes; but this name is usually applied to the larger Discophore, when it is thrown upon the beach and lies a shapeless mass of gelatinous substance on the sand, or is seen floating on the surface of the water. The name gives no idea of the animal as it exists in full life and activity. When we speak of a Bird or an Insect, the mere name calls up at once a characteristic image of

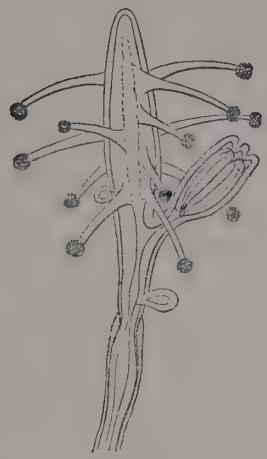
the thing; but the name of Jelly-Fish, or Sun-Fish, or Sea-Blubber, as the larger Acalephs are also called, suggests to most persons a vague idea of a fish with a gelatinous body, — or, if they have lived near the sea-shore, they associate it only with the unsightly masses of jelly-like substance sometimes strewn in thousands along the beach after a storm. To very few does the term recall either the large Discophore, with its purple disk and its long streamers floating perhaps twenty or thirty feet behind it as it swims, — or the Ctenophore, with its more delicate, transparent structure, and almost invisible fringes in parallel rows upon the body, which decompose the rays of light as the creature moves through the water, so that hues of ruby-red and emerald-green, blue, purple, yellow, all the colors of the rainbow, ripple constantly over its surface when it is in motion, — or the Hydroid, with its little shrub-like communities living in tide-pools, establishing themselves on rocks, shells, or sea-weeds, and giving birth not only to animals attached to submarine bodies, like themselves, but also to free Medusæ or Jelly-Fishes that in their turn give birth again to eggs which return to the parent form, and thus, by alternate generations, maintain two distinct patterns of animal life within one cycle of growth.

On shells and stones, on sea-weeds or on floating logs, there may often be observed a growth of exquisitely delicate branches, looking at first sight more like a small bunch of moss than anything else. But gather such a

Coryne mirabilis, natural size.

mossy tuft and place it in a glass bowl filled with sea-water, and you will presently find that it is full of life and activity. Every branch of this miniature shrub terminates in a little club-shaped head, upon which are scattered a number of tentacles. They are in constant motion, extending and contracting their tentacles, some of the heads stretched upwards, others bent

downwards, all seeming very busy and active. Each tentacle has a globular tip filled with a multitude of cells, the so-called lasso-cells, each one of which conceals a coiled-up thread. These organs serve to seize the prey, shooting out their long threads, thus entangling the victim in a net more delicate than the finest spider's web, and then carrying it to the mouth by



Single head or branch of Coryne mirabilis, magnified, with two Medusa buds.

the aid of the lower part of the tentacle. The complication of structure in these animals, a whole community of which, numbering from twenty to thirty individuals, is not more than an inch in height, is truly wonderful. In such a community the different animals are hardly larger than a good-sized pin's head; and yet every individual has a digestive cavity and a complete system of circulation.

Its body consists of a cavity enclosed in a double wall, continuing along the whole length of each branch till it joins the common stem forming the base of the stock. In this cavity the food becomes softened and liquefied by the water that enters with it through the mouth, and is thus transformed into a circulating fluid which flows from each head to the very base of the community and back again. The inner surface of the digestive cavity is lined with brownish-red granules, which probably aid in the process of digestion; they frequently become loosened, fall into the circulating fluid, and may be seen borne along the stream as it passes up and down. The rosy tint of the little community is due to these reddish granules.

This crowd of beings united in a common life began as one such little Hydra-like animal as I have described above, — floating free at first, then becoming attached, and growing into a populous stock by putting out buds at different heights along the length of the stem. The formation of such a bud is very simple, produced by the folding outwardly of the double wall of the body, appearing first as a slight projection of the stem sideways, which elongates gradually, putting out tentacles as it grows longer, while at the upper end an aperture is formed to make the mouth. This is one of the lower group of Radiates, known as Hydroids, and long believed to be Polyps, from their mode of living

in communities and reproducing their kind by budding, after the fashion of Corals.

But if such a little tuft of Hydroids has been gathered in spring, a close observer may have an opportunity of watching the growth of another kind of individual from it, which would seem to show its alliance with the Acalephs rather than the Polyps. At any time late in February or early in March, bulb-like projections, more globular than the somewhat elongated buds of the true Hydroid heads, may be seen growing either among the tentacles of one of these little animals, or just below the head where it merges in the stem.* Very delicate and transparent in substance, it is hardly perceptible at first; and the gradual formation of its internal structure is the less easily discerned, because a horny sheath, forming the outer covering of the Hydroid stock, extends to enclose and shield the new-comer, whom we shall see to be so different from the animal that gives it birth that one would suppose the Hydroid parent must be as much surprised at the sight of its offspring as the Hen that has accidentally hatched a Duck's egg. At the right moment this film is torn open by the convulsive contractions of the animal, which, thus freed from its envelope, begins at once to expand. By this time the little bud has assumed the form of a Medusoid or Jelly-Fish disk, with its four tubes radiating

* See wood-cut, p. 83

from the central cavity. The proboscis, so characteristic of all Jelly-Fishes, hangs from the central opening; and the tentacles, coiled within the internal cavity up to this time, now make their appearance, and we have a complete little Medusa growing upon the Hydroid head. Gradually the point by which it is attached to the parent-stock narrows and becomes more and more contracted, till the animal drops off and swims away, a free Jelly-Fish.

The substance of these animals seems to have hardly more density or solidity than their native element. I remember showing one to a friend who had never seen such an animal before, and, after watching its graceful motions for a moment in the glass bowl where it was swimming, he asked, "Is it anything more than organized water?" The question was very descriptive; for so little did it seem to differ in substance from the water in which it floated that one might well fancy that some drops had taken upon themselves organic structure, and had begun to live and move. It swims by means of rapid contractions and expansions of its disk, thus impelling itself through the water, its tentacles floating behind it and measuring many times the length of the body. The disk is very convex, as will be seen by the wood-cut; four tubes radiate from the central cavity to the periphery, where they unite in a circular tube around the margin and connect also with the four tenta-

cles; from the centre of the lower surface hangs the proboscis, terminating in a mouth. Notwithstanding the delicate structure of this little being, it is exceedingly voracious. It places it-

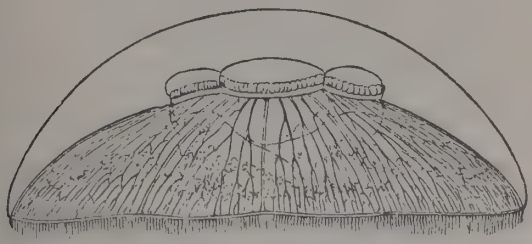
Little Jelly-Fish, called Sarsia, the free Medusa of Coryne mirabilis.

self upon the surface of the animal on which it feeds, and, if it have any hard parts, it simply sucks the juices, dropping the dead carcass immediately after; but it swallows whole the little Acalephs of other Species and other soft animals that come in its way. Early in summer

these Jelly-Fishes drop their eggs, little transparent pear-shaped bodies, covered with vibratile cilia. They swim about for a time, until they have found a resting-place, where they attach themselves, each one founding a Hydroid stock of its own, which will in time produce a new brood of Medusæ.

On the lower side, or what I have called in a previous chapter the oral region of the animal, a wonderfully complicated aparatus is developed. The mouth projects in four angles, and at each such angle a curtain arises, stretching outwardly, and sometimes extending as far as the margin. These curtains are fringed and folded on the lower edge, so that they look like four ruffled flounces hanging from the lower side of the animal. On the upper side of the body, but alternating in position with these curtains, are the four ovaries, crescent-like in shape, and so placed as to form the figure of a cross, when seen

from above through the transparency of the disk. I should add, that, though I speak of some organs as being on the upper and others on the lower side of the body, all are under the convex, arched surface of the disk, which is gelatinous throughout, and simply forms a transparent vaulted roof, as it were, above the rest of the body.



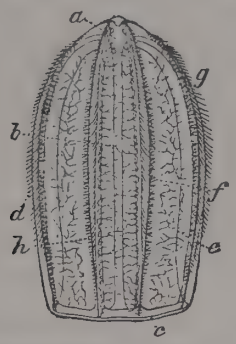
Aurelia flavidula, seen in profile.

When these animals first make their appearance in the spring, they may be seen, when the sky is clear and the sea smooth, floating in immense numbers near the surface of the water, though they do not seek the glare of the sun, but are more often found about sheltered places, in the neighborhood of wharves or overhanging rocks. As they grow larger, they lose something of their gregarious disposition, — they scatter more; and at this time they prefer the sunniest exposures, and like to bask in the light and warmth. They assume every variety of attitude, but move always by the regular contraction and expansion of the disk, which rises and falls with

rhythmical alternations, the average number of these movements being from twelve to fifteen in a minute. There can be no doubt that they perceive what is going on about them, and are very sensitive to changes in the state of the atmosphere; for, as soon as the surface of the water is ruffled, or the sky becomes overcast, they sink into deeper water, and vanish out of sight. When approached with a dip-net, it is evident, from the acceleration of their movements, that they are attempting to escape.

The third order, the Ctenophoræ, are among the most beautiful of the Acalephs. I have spoken of the various hues they assume when in motion, and I will add one word of the peculiarity in their structure which causes this effect. The Ctenophoræ differ from the Jelly-Fishes described above in sending off from the main cavity only two main tubes, instead of four like the others; but each of these tubes divides and subdivides in four branches as it approaches the periphery. From the eight branches produced in this way there arise vertical tubes extending in opposite directions up and down the sides of

the body. Along these vertical tubes run the rows of little locomotive oars, or combs, as they have been called, from which these animals derive their name of Ctenophoræ. The rapid motion



Idyia roseola; one of our Ctenophoræ: *a*, anal aperture; *b*, radiating tube; *c*, circular tube; *d*, *e*, *f*, *g*, *h*, rows of locomotive fringes.

of these flappers causes the decomposition of the rays of light along the surface of the body, producing the most striking prismatic effect; and it is no exaggeration to say that no jewel is brighter than these Ctenophoræ as they move through the water.

RECAPITULATION

1st. The connection of all the known features of nature into one system exhibits thought, the most comprehensive thought, in limits transcending the highest wonted powers of man.

2d. The simultaneous existence of the most diversified types under identical circumstances exhibits thought, the ability to adapt a great variety of structures to the most uniform conditions.

3d. The repetition of similar types, under the most diversified circumstances, shows an immaterial connection between them; it exhibits thought, proving directly how completely the Creative Mind is independent of the influence of a material world.

4th. The unity of plan in otherwise highly diversified types of animals, exhibits thought; it exhibits more immediately premeditation, for no plan could embrace such a diversity of beings, called into existence at such long intervals of time, unless it had been framed in the beginning with immediate reference to the end.

5th. The correspondence, now generally known as special homologies, in the details of structure in animals otherwise entirely disconnected, down to the most minute peculiarities, exhibits thought, and more immediately the power of expressing a general proposition in an indefinite number of ways, equally complete in themselves, though differing in all their details.

6th. The various degrees and different kinds of relationship among animals which can have no genealogical connection, exhibit thought, the power of combining different categories into a permanent, harmonious whole, even though the material basis of this harmony be ever changing.

7th. The simultaneous existence, in the earliest geological periods in which animals existed at all, of representatives of all the great types of the animal kingdom, exhibits most especially thought, considerate thought, combining power, premeditation, prescience, omniscience.

8th. The gradation, based upon complications of structure, which may be traced among animals built upon the same plan, exhibits thought, and especially the power of harmoniously distributing unequal gifts.

9th. The distribution of some types over the most extensive range of the surface of the globe, while others are limited to particular geographical areas, and the various combinations of these types into zoölogical provinces of unequal extent, exhibit thought, a close control over the distribution of the earth's surface among its inhabitants.

10th. The identity of structure of these types, notwithstanding their wide geographical distribution, exhibits thought; that deep thought, which, the more it is scrutinized, seems the less capable of being exhausted, though its meaning at the surface appears at once plain and intelligible to every one.

11th. The community of structure, in certain respects, of animals otherwise entirely different, but living within the same geographical area, exhibits thought, and more particularly the power of adapting most diversified types with peculiar structures to either identical or to different conditions of existence.

12th. The connection, by series, of special structures observed in animals widely scattered over the surface of the globe, exhibits thought, unlimited comprehension, and more directly omnipresence of mind, and also prescience, as far as such series extend through a succession of geological ages.

13th. The relation there is between the size of animals and their structure and form, exhibits thought; it shows that in nature the quantitati differences are as fixedly determined as the qualitative ones.

14th. The independence, in the size of animals, of the mediums in which they live, exhibits thought, in establishing such close connection between elements so influential in themselves and organized beings so little affected by the nature of these elements.

15th. The permanence of specific peculiarities under every variety of external influences, during each geological period, and under the present state of things upon earth, exhibits thought: it shows, also, that limitation in time is an essential element of all finite beings, while eternity is an attribute of the Deity only.

16th. The definite relations in which animals stand to the surrounding world, exhibit thought; for all animals living together stand respectively, on account of their very differences, in different relations to identical conditions of existence, in a manner which implies a considerate adaptation of their varied organization to these uniform conditions.

17th. The relations in which individuals of the same species stand to one another, exhibit thought, and go far to prove the existence in all living beings of an immaterial, imperishable principle, similar to that which is generally conceded to man only.

18th. The limitation of the range of changes which animals undergo during their growth, exhibits thought; it shows most strikingly the independence of these changes of external influences, and the necessity that they should be determined by a power superior to these influences.

19th. The unequal limitation in the average duration of the life of individuals in different species of animals, exhibits thought; for, however uniform or however diversified the conditions of existence may be under which animals live together, the average duration of life, in different species, is unequally limited. It points, therefore, at a knowledge of time and space, and of the value of time, since the phases of life of different animals are apportioned according to the part they have to perform upon the stage of the world.

20th. The return to a definite norm of animals which multiply in various ways, exhibits thought. It shows how wide a cycle of modulations may be included in the same conception, without yet departing from a norm expressed more directly in other combinations.

21st. The order of succession of the different types of animals and plants characteristic of the different geological epochs, exhibits thought. It shows, that, while the material world is identical in itself in all ages, ever different types of organized beings are called into existence in successive periods.

22d. The localization of some types of animals upon the same points of the surface of the globe, during several successive geological periods, exhibits thought, consecutive thought; the operations of a mind acting in conformity with a plan laid out beforehand, and sustained for a long period.

23d. The limitation of closely allied species to different geological periods, exhibits thought; it exhibits the power of sustaining nice distinctions, notwithstanding the interposition of great disturbances by physical revolutions.

24th. The parallelism between the order of succession of animals and plants in geological times and the gradation among their living representatives, exhibit thought; consecutive thought, superintending the whole development of nature from beginning to end, and disclosing throughout a gradual progress, ending with the introduction of man at the head of the animal creation.

25th. The parallelism between the order of succession of animals in geological times and the changes their living representatives undergo during their embryological growth, exhibit thought; the repetition of the same train of thoughts in the phases of growth of living animals and

the successive appearance of their representatives in past ages.

26th. The combination, in many extinct types, of characters, which, in later ages, appear disconnected in different types, exhibits thought, prophetic thought, foresight; combinations of thought preceding their manifestation in living forms.

27th. The parallelism between the gradation among animals and the changes they undergo during their growth, exhibits thought, as it discloses everywhere the most intimate connection between essential features of animals which have no necessary physical relation, and can, therefore, not be understood otherwise than as established by a thinking being.

28th. The relations existing between these different series and the geographical distribution of animals, exhibit thought; they show the omnipresence of the Creator.

29th. The mutual dependence of the animal and vegetable kingdoms upon each other for their maintenance, exhibits thought; it displays the care with which all conditions of existence, necessary to the maintenance of organized beings, have been balanced.

30th. The dependence of some animals upon others or upon plants for their existence, exhibits thought; it shows to what degree the most complicated combinations of structure and adaptation can be rendered independent of the physical conditions which surround them.

31st. The combination in time and space of all these thoughtful conceptions exhibits not only thought, it shows also premeditation, power, wisdom, greatness, prescience, omniscience, providence.

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